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Recent Developments in Laboratory X-ray Microanalytical Techniques for Electronic Structure, Chemical Composition, and Microstructure of Metals and Materials

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Since the start of their development in the 1960s [1], synchrotron x-ray techniques have grown exponentially in use, and now are considered vital to many areas of research [2] spanning from advanced materials to biomedical sciences. These techniques include XAS which provides powerful access to electronic structure, micro/nanoXRF for chemical composition down to ultratrace levels, and x-ray microsocopy. However, demand is still outpacing the availability of synchrotron beamtime, and many synchrotron beamlines are 2-4X oversubscribed.

Laboratory based x-ray techniques offer an alternative to synchrotron radiation for workhorse applications, but many systems have thus far been bottlenecked in performance due to the x-ray source and focusing optics used. In recent years, several major innovations by our company and other groups have been made to drastically improve the brightness of x-ray sources. One concept patented by Sigray uses a target design in which microstructured metals are embedded in a diamond substrate, which due to the superior thermal conductivity of diamond (e.g. over 10X that of tungsten at room temperatures), provides rapid heat dissipation and is further optimized due to the maximized surface contact with the microstructured metal. Another key aspect is the focusing x-ray optic, which has conventionally suffered due to chromatic aberrations and limited brightness preservation for small spot sizes. A newly achieved optic having inner reflecting surfaces of mirrored paraboloids overcomes these limitations and enables the use of such high brightness x-ray source concepts.

In this presentation, we will review the progress we have made with developing the new x-ray source and x-ray optical systems, and discuss how these components enable unprecedented new laboratory capabilities. We will also describe our currently commercialized synchrotron-like laboratory techniques and review their applications, including:

- X-ray absorption spectroscopy for bond lengths and oxidation states for batteries and metals;
- Micro x-ray fluorescence which provides parts-per-million chemical analysis of ultratrace elements simultaneously with major elements at microns-scale resolution for geological applications;
- Talbot-Lau microscopy for simultaneous access to absorption contrast, phase contrast, and darkfield contrast for imaging cracks and voids; and
- Nano x-ray microscopy with outstanding structural resolution imaging down to 30 nm for polymers and cells.

Furthermore, we will conclude with current state-of-the-art and future developments.

References

[1] Balerna A, Mobilio S. Synchrotron Radiations: Basics, Methods and Applications. Germany: Springer; 2015;1:3-27
[2] Bharti A and Goyal N. “Fundamental of Synchrotron Radiations,” Synchrotron Radiation - Useful and Interesting Applications. 2018.